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ABSTRACT

This study addressed the assessment and development of problem-solving skills of college students. A mathematics-oriented computer-assisted instruction (CAI) program with an embedded general problem-solving strategy was developed. A related computer-managed instruction (CMI) module maintained student progress and phased out the problem-solving assistance as students became more skilled at solving problems. Effectiveness was evaluated by pre- and post-tests and questionnaires administered to 37 students who used the CAI program and a control group of 23 students who received no CAI. Improvement in the mean test scores of the group using CAI was approximately twice that of the control group, and responses to the questionnaire showed that the students in the experimental group enjoyed using the CAI program and felt that they learned from it. Extracts from the pre-/posttests and a copy of the questionnaire are appended. (45 references) (Author/MES)

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Assessment and Development of Student Problem-Solving Skills Using Computer-managed and Computer-assisted Instruction

by

William C. Juchau

Cohort 1

A Major Practicum Report Presented to the Ed.D. Program
In Computer Education in Partial Fulfillment of the
Requirements for the Degree of Doctor of Education

NOVA UNIVERSITY

1988

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ABSTRACT

Assessment and Development of Student Problem-Solving Skills Using Computer-managed and Computer-assisted Instruction.

Juchau, William C. 1988: Major Applied Project, Nova University. Ed.D. Program in Computer Education.

Descriptors: Computer Assisted Instruction/Computer Manager Instruction/Problem-solving/Microcomputers/ Pascal Programming/Mathematics/Tutoring Systems.

This practicum addressed the assessment and development of problem-solving skills. College faculty suggested students often lack a problem-solving strategy to apply to new problems. The current literature provided no "best" way to teach problem-solving skills. Writers suggested "detached courses in problem-solving" and "embedded problem-solving strategies in existing subject area courses" as two possible solutions.

This author developed a mathematics-oriented, computer-assisted instruction (CAI) program with an embedded general problem-solving strategy. A related computer-managed instruction (CMI) module maintained student progress and "faded" the problem-solving "help" as students became skilled in solving the problems.

Effectiveness was evaluated by pretesting and posttesting students who took the CAI program and control groups who received no CAI and by student questionnaires.

No statistically significant difference was found in the improvement of test scores between the experimental groups. The improvement in the mean test scores, however, of the group that that used the CAI program was about twice that of the control group. Results from the questionnaire showed that the students enjoyed using the CAI program and learned from it. Favorable improvement in the treatment group's test scores suggested that more research would be appropriate.

The practicum's CAI and CMI program will be used by the author's college to find and help remediate students with poor problem-solving skills.

CHAPTER I

INTRODUCTION

Socio-Economic and Geographic Factors

The author works as an Assistant Professor of Business Administration at a small, private college. The college offers three academic programs providing a liberal arts curriculum in accounting, arts, business administration, communications, drama, economics, music, nursing, religion, science, and several other fields. One program addresses the needs of traditional, four-year college students, and several other programs address the needs of part-time students. (Part-time students attending classes that meet one or two evenings each week must have an associate's degree and a full-time job.) The traditional college program enrolls about 2,000 students. Nearly 700 associate's degree students enroll in an evening, baccalaureate degree-completion program each semester. Additionally, about 100 students enroll in the college's third program, an evening master's degree program in business administration. More mature students usually enroll in the two evening programs. Their ages average about 30 years versus

about 20 years in the traditional program. The college, located in a semi-urban city of about 100,000 residents, relies heavily on the local community and state for students. Currently, only 30 percent of the students enroll from outside the state, and that percentage may decrease. The city's major industries are agriculture, mining, small manufacturing, and tourism. Both the city and state are growing rapidly.

Author's Work Setting and Role

The author develops and teaches computer-related courses within this environment with primary responsibilities in the computer information systems area, including introductory computer courses, programming, systems analysis and design, database, project management, and related topics. The author teaches at the undergraduate and graduate levels in the day and evening programs, develops curriculum for computer-related courses, and often consults in academic and administrative computer systems development and implementation.

CHAPTER II

STUDY OF THE PROBLEM

Problem Description

The college stresses teaching of problem-solving skills versus rote memorization of knowledge or facts. The Chairperson of the Psychology Department routinely determines students' problem-solving aptitudes with diagnostic tests. This testing has identified an important problem involving a portion of the students -- particularly those in the evening program. Ideally, all students should have the same high level of problem-solving skills. However, some of the evening program students display a lower skill level than the day program students. The department chair has verified this shortcoming by comparing test scores of the two groups over the last several years. The problem is to identify those students not possessing a high level of problem-solving skills and to correct the shortcoming.

Problem Documentation

Diagnostic testing results and interviews with faculty members provided evidence of the problem. As mentioned above, evening students appeared to test lower and to exhibit a lower degree of problem-solving ability in classroom assignments.

A faculty member, who teaches in the evening program, saw the problem as follows:

> Candidates for the nursing degree, although highly motivated in their studies, appear to lack some basic problem-solving skills. This is reflected, for example, in lower achievement on problem-solving skills tests when compared to college students in the other study programs. The reasons for this apparent shortfall cannot be ascertained. Perhaps, the candidates' early undergraduate studies did not stress problem-solving activities or opportunities. The candidates' work environment may primarily be composed of conditions that stress lower level cognitive skills as opposed to problem-solving and decision-making opportunities. In any event, to ensure that the candidates have the appropriate skills when they leave the baccalaureate program, the college needs a means of identifying students with poor problem-solving skills and a method of improving those skills where necessary.

Causative Analysis and Related Literature

This quote suggested several possible causes of the problem of poor problem-solving skills. First, the students may lack academic preparation in courses tending to improve problem-solving skills. Students in

the evening program tend to shun mathematics-oriented courses, or, for that matter, any course traditionally requiring reasoning, logic, problem-solving, study, and hard work. They are, in this regard, similar to the day student. Piaget, a developmental psychologist, addressed the relationship of logical and mathematical structures to the process of cognition. The logico-mathematical structures form, according to Piaget, a system much like a "field of force" that clicks into operation when the student encounters a problem (Flavell, 1963). Secondly, the evening students' vocational work experience may seldom stimulate the development of good problem-solving skills. Many jobs encourage a "cookbook" or "check list" approach to problem-solving and discourage individual creativity in finding or developing new solutions. Nurses, for example, are not expected to seek innovative solutions to problems. They are often told to follow specified procedures and to seek help from a superior when the existing circumstances are not covered. Piaget's theories also apply here. Effective problem-solving requires thinking of all "possibilities" and "form" of solutions as well as the available concrete facts. Dr. Leonard Huber (1985:43) reflected on Piaget's discussion of the "formal operational" thinking

patterns developed by adolescents and adults. "Before the invention of the printing press few people even reached the formal operational stage. They simply lacked the intellectual stimulation." Vocations void of problem-solving applications may foster similar results. Thirdly, the evening student may synthesize few of the problem-solving concepts from the various course offerings -- a shortcoming resulting from the somewhat disjointed evening schedule and part-time staff. Course scheduling and staffing constraints combine with student work constraints to prevent the normal and preferred course progression that would maximize the student's synthesis of various course concepts. Thus, in the evening program, there is probably less carryover of problem-solving concepts from one course to another (Stanger, 1982). Faculty employed full-time in the day program stabilize and integrate the curriculum by involving themselves in overall curriculum design and by teaching several integrated courses. This integrated environment may help traditional students synthesize problem-solving concepts. Conversely, the adjunct faculty members in the evening program lack the same degree of interest in the overall curriculum and, therefore, fail in the inter-disciplinary synthesis

necessary to transfer problem-solving skills from one course to another. Students are left with the crucial job of synthesizing problem-solving skills introduced in various ways in many courses. Finally, even in an integrated environment, students may not transfer requisite problem-solving skills from one course or domain to another (Newell, 1980). For example, students may not transfer problem-solving skills that are learned in mathematics or chemistry classes to other courses (Gagne, 1980). Experts, reportedly, use a "general problem-solving approach" that can be applied to many different problems, while novices lack a universal "approach" to problem-solving (Chi, Feltovich, and Glaser, 1980). The college may err in thinking that the existing curriculum develops general problem-solving skills when it does not.

CHAPTER III

EXPECTED OUTCOMES AND EVALUATION INSTRUMENTS

Statement of General Goals

The practicum goals included identifying students lacking problem-solving skills and providing a method of improving those skills. The practicum outcomes included a method for identifying students who possess a low skill level in problem-solving and an effective educational computer program for improving those skills. Several instruments were used to evaluate the practicum's outcomes. Two reasoning tests measured the success of the experimental CAI treatment in improving problem-solving skills. Lowry-Lucier Reasoning Tests A and B served as pretest and posttest instruments, and a statistically significant improvement in the means was expected. The students' answers to a two-part written questionnaire given to the treatment group determined their recall and understanding of the embedded problem-solving approach. (For examples of these tests and questionnaires see Appendix A -- Test and Evaluation Instruments.) The questionnaire, given shortly after the CAI, contained a quiz that determined the students' knowledge of the generalized

approach to problem-solving. Each student was expected to list, in the proper order and without error, the four key words in the 4C's general problem-solving strategy. Questions also addressed attitudes related to the practicum solution. The Statistical Package for the Social Sciences (SPSS), a statistics program, was used to analyze the pretest and posttest data. The null hypothesis suggested no statistically significant difference in the pretest and posttest means of the treatment group and the control group of students at a level of significance of 0.05. Analysis of variance and covariance methods were used to analyze statistically the factors of student age, grade point average (GPA), and SAT scores.

CHAPTER IV

SOLUTION STRATEGY

Discussion and Evaluation of Solutions

This practicum integrated concepts learned in several study areas; however, the major concepts and solutions strategies stemmed from the study areas of Learning Theory, Courseware, and Programming. The study areas addressed concepts of teaching a general problem-solving strategy, suggested the use of CAI to assist in teaching the strategy, and provided the techniques and programming tools to create the CAI-CMI program. The Learning Theory area addressed teaching students a general purpose problem-solving strategy. Chi, Feltovich, and Glaser (1980) noted that "experts" approach problems with a particular problem-solving style, or heuristic, that they evidently learn and novices lack. Derry and Murphy (1986) stated that research implied the existence of domain-general (versus domain-specific) heuristic planning models, or "metastrategies," that are effective in problem-solving. For example, a general model of problem-solving might entail steps in (a) analysis and goal identification, (b) planning a strategy, (c)

strategy, and (e) changing the strategy. Baron (1981) stated that a major advantage of training such a problem-solving model was that the strategy would help students to control their "stylistic" propensities in thinking. The impulsive student, according to Baron, could be trained to benefit from more reflective thinking in appropriate circumstances. Metacognitive experiences, or thinking about how we learn, can improve the acquisition and use of learned skills (Flavell, 1981). Although more research is needed, the conclusion that training in metastrategy techniques has produced modest, statistically significant gains in student academic performance is empirically supported (Dansereau et al., 1979). Unfortunately, no agreement existed on the "best" model for problem-solving, and numerous problem-solving models were available. Derry and Murphy (1986) reported that more than twelve different metastrategy models are popularized in various forms of training. Kellis (1985) analyzed many existing problem-solving models and found four conceptually similar "steps" present in ten different models. The proliferation of these numerous problem-solving models or metastrategies could generate instructional conditions that are confusing and interfering. This carrying out the strategy, (d) checking results of the

practicum implemented the Four C's Learning Plan (4C's) model suggested by Derry and Murphy (1986). The four C's are as follows: (1) Clarify the problem (identify goals, alternatives, and constraints), (2) Choose an alternative (costs versus benefits analysis of alternatives, and decision-making), (3) Carry out the decision, (4) Check the results (evaluation, review, and iteration). Models similar to the above problem-solving strategy have been suggested for diverse areas such as educational curriculum design, computer systems analysis, and military mission planning. While not a panacea, the above 4C's model presented a useful problem-solving model with wide application.

Several possibilities existed for training in a general problem-solving strategy. One approach treated the strategy as a "stand-alone" curriculum. Here, "teaching a problem-solving strategy" became the course objective replacing the teaching of specific subject matter. A danger of this "detached" training method is that the strategies themselves are addressed at the lowest level of learning skills. The problem-solving strategies are reduced to lists to be memorized -- level one on Bloom's learning hierarchy (Bloom, 1956). Embedding the problem-solving strategy within the academic subject or

basic skills area provided a better solution. This approach linked the problem-solving strategies to the real-world, subject matter environment (Sternberg, 1983). Thus, mathematics teachers would use the metastrategies to explain specific problem-solving techniques, while language arts teachers would explain how reading and memorization tactics fit into the strategies, and computer science teachers would explain computer systems development using the same problem-solving framework (Derry and Murphy, 1986). However, embedded training in problem-solving may result in a loss of "generality" since the student must transfer the problem-solving strategies to other subject areas. The preferred approach is likely a compromise combination of the detached and embedded approaches to training in problem-solving strategies (Beyer, 1987). Thus, one alternative solution to the practicum problem was to create a formal course in problem-solving strategies. The general problem-solving strategies could be introduced into the curriculum in this course and reinforced within the subject area courses. This solution would entail adding another course to an already full schedule and making other curriculum revisions. The Courseware study area suggested how the

computer might effectively help solve the practicum problem. Another option existed for developing a computer-assisted instruction (CAI) program with a problem-solving strategy (the 4C's) embedded within the subject-matter course or exercise. The strength of this approach would be the extended use of problem-solving skills in a realistic subject-matter context (Jones et al., 1985). This approach would require no change to the curriculum since the CAI program could be used individually outside the formal course offerings. Furthermore, the integration of a computed-managed instruction (CMI) module with the CAI program would automatically maintain student progress and provide data for identifying students with problem-solving or subject-matter deficiencies. Derry and Murphy (1986) described a job-skills CAI program (JSEP) using a system controlled prompting method that (1) prompted students at selected points to recall and use certain problem-solving techniques; (2) analyzed student performance to help determine when prompts were no longer needed; and (3) gradually phased out prompts in advanced stages of instruction when evidence existed that the student was spontaneously applying problem-solving strategies.

Description of Selected Solution

Based on the time and cost constraints associated with the curriculum, a CAI approach similar to the above JSEP program appeared most appropriate as the practicum solution. The Psychology Department used a manual, mathematics-oriented problem-solving test to assist in assessing student skills. Table 1 shows examples of

Table 1

Examples of XYZ Problems

1.	2.	3.	4.
Z + X ---- XY	X Y + Y ---- YY	X X + X ---- YX	X Y + Y ---- XX

the problems which required the student to substitute a singular, integer value from zero through nine for the letters X, Y, or Z. The problems were constructed such that only one combination of values resulted in a correct solution. Although the problems would appear to favor algebraic solutions, the fastest way to solve the problems entails the development of a series of heuristic techniques (based on such concepts as arithmetic carry, answer approximation, and minimum or maximum values)

that apply to the problems. The existing test format, familiar to the department faculty, formed the basis for a CAI-CMI program entitled Computer-assisted Problem-solving (CAPS).

Report of Action Taken

A prototype screen format and user interface was created during the CAI program design. This "throwaway" prototype tested the users' (i.e., representatives of the Psychology Department) acceptance of the screen layouts.

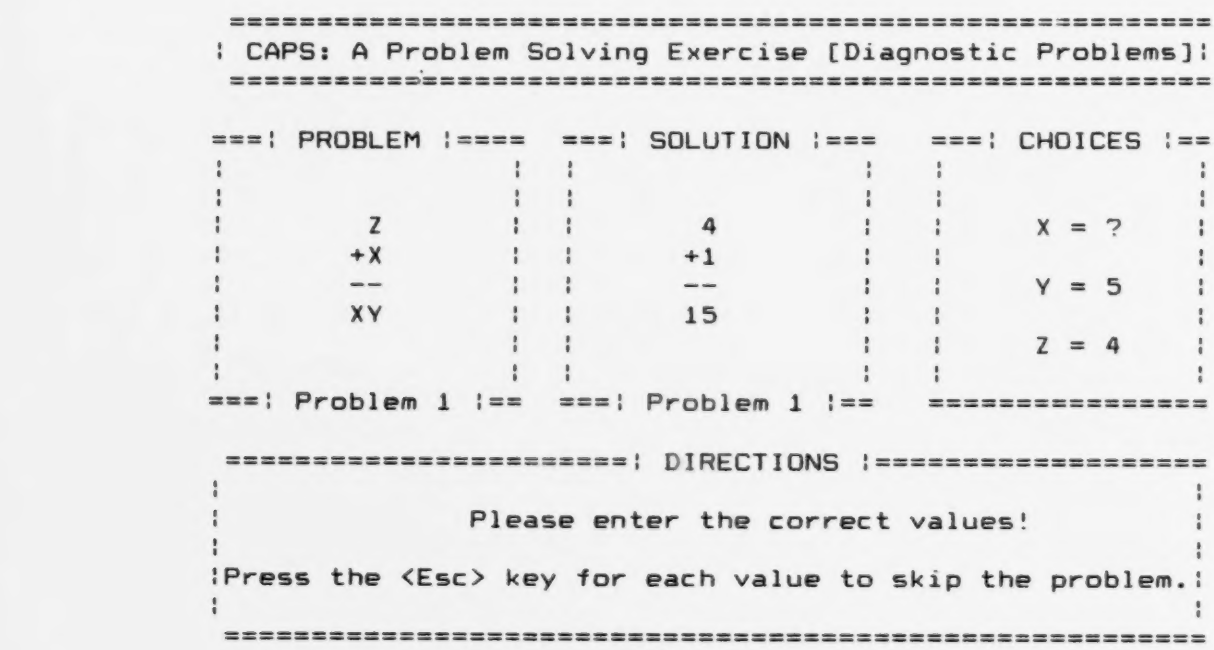


Figure 1

Example of Screen Layout for CAI Program

(Modified to fit on this page and print without graphics.)

Figure 1 shows the program's screen format. Full-scale program design efforts started after acceptance of the screen layouts and user interface. This prototype approach used good system and program design techniques by ensuring that the output was in the desired format before making extensive coding efforts. Each program task was then identified and recorded in a hierarchy chart (or program structure chart).

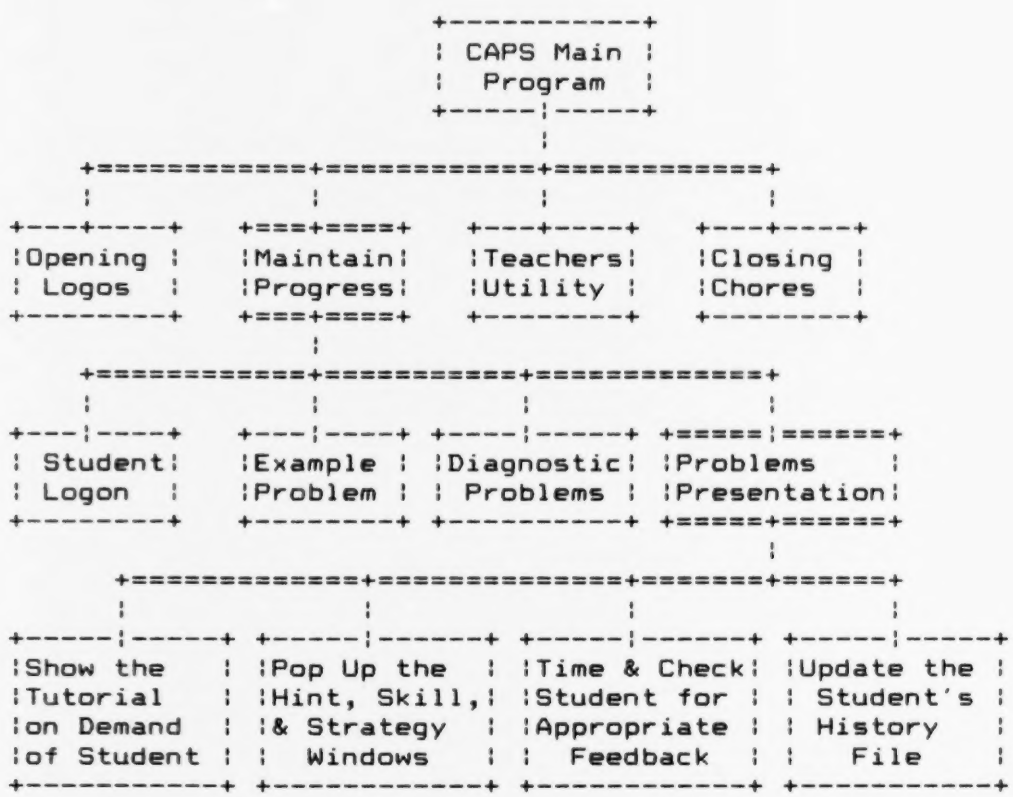


Figure 2

CAPS Program Hierarchy Chart (Structure Chart)

Figure 2 shows the final hierarchy chart for the main program.

```
WHILE Student is not finished
¦
¦   WHILE First Time for Exercises
¦   ¦ IF (Diagnostic NOT taken) AND not Escape DO
¦   ¦ ¦
¦   ¦ ¦ Diagnostic Test
¦   ¦ ENDIF
¦   ¦ IF a diagnostic problem was missed
¦   ¦ ¦ Answer first diagnostic problem missed
¦   ¦ ENDIF
¦   ENDWHILE (First time for exercise)
¦
¦   WHILE Problem is missed AND not escape
¦   ¦ Answer first problem not correct
¦   ¦ Go to next problem not answered correctly
¦   ENDWHILE
¦
¦   WHILE Skills bad AND not escape DO
¦   ¦ Answer random problems related to specific skills
¦   ENDWHILE
¦
¦   WHILE Bugs present AND not escape DO
¦   ¦ Answer random problems related to specific bugs
¦   ENDWHILE
¦
¦   WHILE (a problem not in standards) AND not escape
¦   ¦ Answer substandard problems again
¦   ENDWHILE
¦
ENDWHILE (not escape)
Update Files
EXIT to DOS
```

Figure 3

Example Program Pseudocode (Progress Module)

Pseudocode and design documentation was created for each program task. An example of the pseudocode is shown in Figure 3. The program was written in the Pascal language using modular, top-down programming techniques to enhance program reliability and maintainability.

The embedded problem-solving strategy was presented as a tutorial on the 4C's method of problem-solving and as "pop-up windows" that appear periodically during the exercises. This brief 4C's problem-solving tutorial was recallable on demand (by pressing "t") throughout the program. The pop-up windows appear as a function of the student's responses to the exercises. The student's time-on-task, number-of-tries, and choice-of-answer were used to determine the proper help and strategy guidance to provide the student via the windows. The CMI portion of the program enabled automatic student tracking and skill level recording. "Intelligent" CAI (ICAI) concepts assisted in creating the CMI module (Rambally, 1986). Specifically, the program used a listing of skills and "logic bugs" (i.e., erroneous approaches to solving the problems) that were fundamental to the mastery of the subject area material. Here, the skills and bugs dealt primarily with finding heuristic techniques for solving the problems.

SKILLS:

Status	Skill Description
3	Considering MAXIMUM values of numbers.
-3	Considering MINIMUM values of numbers.
3	Using correct CARRY value to next column.
0	Choosing ODD OR EVEN values where needed.
3	Using APPROXIMATION of the answer.
-1	Using SUBGOALS to help solve the problem.

LOGIC BUGS:

Status	Bug Description
-1	Entering numbers that DO NOT ADD UP.
-3	Using SAME NUMBER for different letters.
1	MULTIPLYING not adding for solution.

Figure 4

Skills and Logic Bugs Used in CAPS CAI Program
(Condensed from Teacher's Utility Module)

Figure 4 shows the author's list as implemented in the CMI module. As the student responded to the problems, the appropriate skill or bug "status" was adjusted by plus or minus 1 accordingly. A status range of -3 to +3 was used in the CAI program to provide remedial problem presentation and was reported to the teacher through the CMI module. A teacher module was integrated into the CMI module of the program. Holding down the "Alt" key on the computer keyboard and pressing "222" on the numeric keypad activates a menu of options that a teacher can use to monitor and manage students.

```
Student   D I A G N O S T I C   T E S T   Statistics

Last Name: < JUCHAU >              Password: < 1 >
Date Started: 4-16-88              Data File: STUDENT.DTA

  Problem Number ==>   1     2     3     4
   Number of Tries:    3     1     3     1
On Task Time [sec]:   29     1     3     1
Problem Right?[=1]:    0     0     0     0

Correct Ans:   0                   Total Task Time:      34.0
% Correct:  0.0                    Total Window Time:     0.0
Avg Time of Correct Ans: 0.0       Total Exercise Time: 34.0

Press <Esc> to EXIT        Press the <SPACE BAR> to CONTINUE
```

Figure 5

Teacher's Report Showing Student Diagnostic Results
(Compressed from Teacher's Utility Module)

```
Student    E X E R C I S E    S C O R E S   Status

Last Name: < JUCHAU >              Password: < 1 >
Date Started: 4-16-88              Data File: STUDENT.DTA

Problem ==>  1     2     3     4     5     6     7     8
   Tries:    5     5     0     0     0     0     0     0
Task[sec]:  30    19     0     0     0     0     0     0
  Window:   75    83     0     0     0     0     0     0
Right[=1]:   0     0     0     0     0     0     0     0

             9    10    11    12    13    14
             0     0     0     0     0     0
             0     0     0     0     0     0
             0     0     0     0     0     0
             0     0     0     0     0     0

Correct Ans:   0                   Total Task:      0.82 mins.
% Correct:  0.0                    Total Window:    2.63 mins.
Avg Time of Correct Ans: 0.0       Total Exercise:  3.45 mins.

Press <Esc> to EXIT     Press the <SPACE BAR> to CONTINUE
```

Figure 6

Teacher's Report Showing Student Exercise Results
(Extracted from Teacher's Utility Module)

Figures 5 and 6 show the first two teacher's screens.

Selected faculty and students tested the program during development. These test personnel provided comments and suggestions for improved or modified versions of the program. The testing also provided standards of difficulty for the various CAI problems used in later program development. In October of 1987, the CAI program was field tested with a group of twelve students. Two shortcomings were identified during the test. First, the students were not reading the "help" windows that were presented to them. In their eagerness to "get on with the problems," they cycled quickly through the pop-up windows that provided hints and the general problem-solving strategy. Second, there was no way for the students to return to the 4C's tutorial once it had been viewed. Both of these problems were addressed in revisions to the program.

During March and April 1988, an experiment was conducted using groups of students randomly selected by the college registrar. The treatment group was composed of two intact sections of about 44 students enrolled in an introductory computer course. The control group consisted of about the same number of students enrolled in a psychology course. Both groups took the pretest and posttest. The treatment

group had a two-week period before the posttest during which they were told to use the CAPS program (to assist in developing a general problem-solving strategy). The treatment group completed a questionnaire after the posttest. The results and analysis of the experiment and questionnaire are presented in Chapter V.

CHAPTER V

RESULTS, IMPLICATIONS, AND RECOMMENDATIONS

Evaluating the practicum objectives of identifying and removing shortfalls in student problem-solving skills required attention to several important and different educational outcomes. First, the CAI-CMI program was to provide a means to diagnose and remediate student problem-solving deficiencies. To meet this goal the CAI-CMI program had to be easy to use, error free, and pedagogically sound. The effectiveness of this outcome was measured by student opinions expressed in a questionnaire and through examination of the program's content and operation. Secondly, the program attempted to "teach," in a somewhat subliminal mode, a general problem-solving approach. A brief "quiz," administered with the questionnaire, verified accomplishment of this outcome. Finally, the program was to improve problem-solving skills. An experiment tested the effectiveness of the CAI program as well as the general problem-solving strategy.

Results

The practicum implementation created a CAI-CMI program, entitled Computer-assisted Problem Solving (CAPS). The program's design and coding consumed two man-years of effort. The CAI component of the program used modern CAI screen design techniques from writers such as Jesse M. Heines (Heines: 1984). All CAI screens, for example, were divided into functional areas (e.g., orientation information, directions, responses, error messages, etc.) providing the user a consistent interface throughout the program. "Pop-up windows" presented information without cluttering the screen and without breaking the program's continuity. This window technique presented the general problem-solving strategy and reinforced it during the solving of the mathematics subject area exercises. Concurrently, the CMI program component provided ease and flexibility in student tracking and conserved computer memory by utilizing a linked-list, dynamic data structure for the student data base. The executable CAI-CMI program (CAPS), that contains over 5000 lines of source code, is provided on a 5 1/4" diskette as an enclosure to this report. The program runs on an IBM or compatible computer with MGA or CGA video adapters, 256KB memory,

and one 360KB disk drive. Details for obtaining the source code are provided in Appendix C.

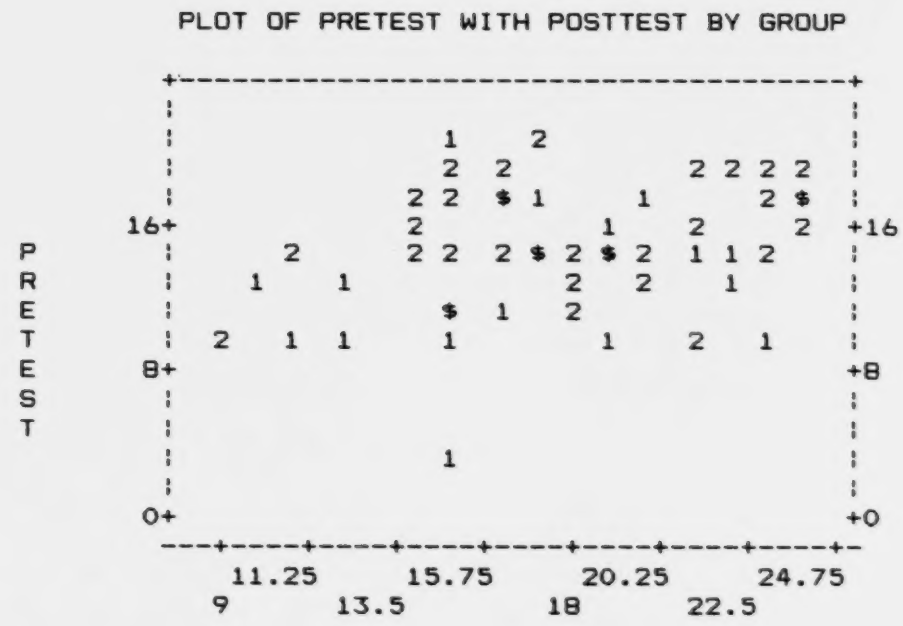
Statistical analysis of the experiment used the microcomputer version of the Statistical Package for Social Sciences (SPSS/PC+).

Table 2

Summary Statistics for Pretest and Posttest Scores

	PRETEST		POSTTEST	
	Control	Treatment	Control	Treatment
Cases	37	23	37	23
Mean	16.270	13.087	18.378	17.087
Std Err	.550	.793	.665	.873
Median	16	13	18	17
Mode	14	9	15	15
Std Dev	3.347	3.801	4.044	4.188
Variance	11.203	14.447	16.353	17.538
Kurtosis	-.030	.337	-.846	-1.071
S E Kurt	.759	.935	.759	.935
Skewness	-.169	-.198	-.201	-.075
S E Skew	.388	.481	.388	.481
Range	15	17	15	14
Minimum	9	4	9	10
Maximum	24	21	24	24

Summary statistics for the pretest and posttest scores are shown in Table 2.



Notes: 60 cases plotted.
1 = Plotting symbol of Treatment Group.
2 = Plotting symbol of Control Group.
$ = Multiple occurrence of data.

Figure 7
Scatterplot of Pretest and Posttest Scores
by Treatment and Control Group

Figure 7 is a scatterplot of the test scores by treatment and control groups.

Table 3

Statistical T Test Results
Independent Samples of Groups
Separate Variance Estimate

	PRETEST	POSTTEST	DIFFERENCE
t Value	-3.30	-1.18	1.60
Degrees of Freedom	42.31	45.54	42.88
2-Tail Prob.	.002	.245	.118

Table 3 presents the results of statistical analysis using the Student's t test.

Table 4

Correlation Coefficients for Selected Variables

Corr:	PRE	POST	DIFF	AGE	GPA	SAT
PRE	1.	.3570*	-.5589**	.0298	.3069	.3431*
POST	.3570*	1.	.5750**	.1270	.2619	.4582**
DIFF	-.5589*	.5750*	1.	.0867	-.0364	.1062
AGE	.0298	.1270	.0867	1.	.1731	.0878
GPA	.3069	.2619	-.0364	.1731	1.	.3181*
SAT	.3431*	.4582*	.1062	.0878	.3181	1.

N of cases: 55 1-tailed Signif: * - .01 ** - .001

Table 4 provides the correlation coefficients for other variables that may affect the experiment's outcome.

Table 5

Student Questionnaire Responses

	Strongly Agree	Agree	Don't Know	Disagree	Strongly Disagree
1. I am comfortable when using a computer.	17%	61%	16%	6%	0%
2. Mathematics is one of my stronger subjects.	17%	50%	0%	17%	17%
3. The instructions for solving the problems were clear.	28%	56%	17%	0%	0%
4. The program had more than one objective.	11%	39%	44%	6%	0%
5. I improved at solving the problems as I progressed.	0%	61%	22%	11%	6%
6. The problems were too hard.	0%	6%	39%	50%	6%
7. The problems were too easy.	6%	11%	39%	33%	11%
8. The "windows" or "hints" were distracting.	0%	28%	17%	39%	17%
9. The "hints" were helpful.	11%	50%	11%	11%	17%
10. I read the "hints."	22%	56%	6%	11%	6%
11. I was challenged by the problems.	22%	61%	11%	0%	6%
12. I had fun doing the problems.	17%	56%	11%	6%	11%
13. I understood the objective of the program.	6%	33%	50%	0%	11%
14. The "hints" were always the same.	0%	11%	39%	44%	6%
15. I felt I was being tested.	6%	28%	17%	44%	6%
16. The mechanics of entering the answers were simple.	28%	44%	11%	11%	6%
17. I could easily see the results of my choices.	33%	50%	11%	0%	6%
18. The math content was much too easy.	6%	17%	28%	28%	22%
19. I enjoyed doing the problems.	17%	50%	11%	11%	11%
20. I learned from the exercise.	0%	44%	39%	0%	17%

Table 5 is a summary of student responses to the questionnaire (Appendix A) given to the treatment group. A copy of the Subject Consent and Release Form used in the experiment is in Appendix B.

Table 6

General Strategy Quiz Results

Provided Terms	*Correct Response	Percent Responding with # 1	2	3	4
Connecting			12%		
Cataloging		6%	12%		12%
Choosing	2		*17%		
Carrying	3			*6%	
Classifying		12%	44%	6%	
Clarifying	1	*33%	12%	6%	
Correcting				12%	44%
Checking	4			44%	*44%
Capitulating					

Note: Total of 59 percent of the students selected the correct terms, but not all in the correct order.

The results of a quiz (Appendix A) given to students in the experimental treatment group are shown in Table 6.

Implications

Robert M. Gagne (1977:36), addressing the subject of learning problem-solving skills, stated that

> Surely, not enough is yet known about how to arrange the conditions of learning so that effective cognitive strategies will be learned. For one thing, the strategies themselves have not been identified and described -- most of them are obviously more complex than our example of the mnemonic system. It seem probable, too, that a learner's cognitive strategies improve in increments over long periods of time, rather than being totally learned in a few days, weeks or months.
>
> . . . .
>
> In order to solve a problem, the learner must be able to recall relevant rules that have been previously learned. (p. 162)
>
> . . . .
>
> The evidence of experimental studies concerning the use of discovery in problem solving certainly does not demonstrate that higher-order rules must be learned by discovery (see Ausubel, 1968, pp. 471-473). In much adult learning, for example, the guidance provided by verbal instructions is so complete that the rule to be learned is stated verbally during the course of learning. (p. 164)
>
> . . . .
>
> To summarize, discovery or problem solving involves the combining of previously learned rules into a new higher-order rule, which "solves" the problem and generalizes to . . . other problems of the same type. Problem solving occurs when the instructions provided the learner do not include a verbally stated "solution," but require the construction of such a solution "on one's own." . . . But the capability acquired by this means does not appear to differ in a fundamental sense from that acquired when instructions include the statement of a "solution" (unless, of course, the latter is learned simply as a verbal chain). What is learned in either case is a higher-order rule, which is based upon some previously learned simpler rules. (p. 165)

CAPS, as implemented in the practicum, attempted to address both the identification of the higher-order rules of problem-solving and the discovery of their application through a problem-solving exercise.

The CAPS program was meant to be "user-friendly" -- a design concept not easily implemented. The results of the student questionnaire seemed to show achievement of the design goal. For example, 72 percent of the students found it simple to enter the problems' answers (Question 16), and 84 percent found the instructions clear (Question 3). Most students could see easily the result of their choices (Question 17 -- 83 percent). Three quarters of the students had fun doing the problems (Question 12 -- 73 percent), and only a third felt they were being tested (Question 15 -- 34 percent).

Of equal concern, was the goal of effectively presenting the general problem-solving strategy without distracting the student from the subject area material. Clearly, the windows that exist for presentation of general problem-solving strategies and other help must not overshadow the subject area objectives of the CAI program. Only 28 percent found the "hint" windows distracting or not helpful (Questions 8 and 9). Conversely, 61 percent found the windows helpful. About

half the students recognized the program's inherent dual objectives (Questions 4 and 13). The students did not expect a quiz on the "4C" words and, therefore, did not attempt to memorize them. As such, the quiz results (in Table 6 above) are commendable. Nearly 60 percent of the students could recall the unordered words. However, knowledge of the words -- or even of the general problem-solving concepts -- are low-level educational objectives (Bloom, 1956). The desired educational outcome was the student's ability to use the problem-solving method in new, diverse environments. The practicum experiment attempted to test the program's effectiveness in meeting this objective.

The experiment, as described in Chapter III and summarized above, attempted to demonstrate that the treatment group (or those taking the CAI program) would do better on later problem-solving tasks. Statistical analysis of the experiment's data does not clearly support this assumption. Unfortunately, a significant difference exists in the pretest means of the control and treatment groups. This should not be if both groups were randomly sampled from an homogeneous population. The flaw in experimental design resulted most likely from the groups being pre-existent

or intact. No significant difference occurred in the posttest means of the groups. An ideal experiment should begin with equal group means and, after treatment, end with a significant difference in the mean scores of the groups. In this respect, the experiment appears to have failed -- at least it failed to reject the null hypothesis that there was no statistically significant difference in the groups after the treatment and allow acceptance of the alternative hypothesis. However, the experimental data did support, at the 88 percent confidence level, a significant "improvement" in the test score means. The treatment group started with a lower mean and improved significantly more than the control group (See Tables 2 and 3). The gravity of a Type I error may not warrant accepting an 88 percent confidence level, but it suggests careful review of the data to preclude blind acceptance of the statistical findings and rejection of the null hypothesis. There was a significant correlation of grade point average (GPA), and Scholastic Aptitude Test (SAT) scores with pretest and posttest scores (See Table 4). These variables were intuitively linked to problem-solving skill level, the experimental data demonstrated a statistically

significance correlation. As expected, there was a statistically significant correlation between the pretest and posttest scores.

Recommendations

The CAPS program is a working CAI-CMI program with potential for addressing the practicum objectives. CAPS used current and effective CAI techniques to present a general problem-solving strategy embedded within a subject area. The CMI module allowed the tracking of student progress and skill level for diagnostic and remedial purposes. More, however, needs to be done to refine the CAPS program and to show that it effectively and efficiently solves the practicum's stated problem. First, experimental study of the CAPS program (or its revisions) should continue. A larger, randomly selected group of students should be used for the next control and treatment groups. Samples paired by age, sex, GPA, SAT, and major would help to control some of the intervening variables associated with the experimental design. The CAPS program should be revised to make the subject area component intrinsically more motivating. The algebraic XYZ problems were interesting, but sustaining student interest and, therefore, attention

might be better achieved by matching the subject area to students' particular study areas or interests.

A logical extension of the CAPS program is a CAPS-like authoring system that would allow an educator to select the subject area problems, required skills, and logic bugs associated with a particular environment. The environment would not have to be mathematics-oriented. Many educational areas, such as business or economics, could benefit from the application of a general problem-solving strategy. A "generative" CAI module (Hoffman, 1975) that develops new subject area problems of various difficulties based on student skills and predetermined algorithms for problem creation (and problem-solving) would be an even more valuable addition to the CAPS program.

Dissemination

The author's college will benefit from the practicum in several ways. Since no method existed for identifying students with deficiencies in problem-solving skills, CAPS will provide the Social Science Division a means of diagnosing and tracking these students. Not enough is known of methods for improving problem-solving skills, and educators may be spending too little time

addressing the problem. Dissemination of the CAPS program within the college will no doubt cause significant debate as to the merits of a general problem-solving strategy and the best means for teaching it to students. Finally, if faculty can be inspired to modify the subject area content and use the CAPS program design in their courses the practicum will be perpetuated.

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APPENDICES

APPENDIX A

EXAMPLE TEST AND EVALUATION INSTRUMENTS

(Extract from)

LOWRY-LUCIER REASONING

Test A

DIRECTIONS: Each answer is a day of the week. Sunday is always the first day of the week for answers to problems. For Sunday, write the number 1 in the answer column. For Tuesday, write the number 3 in the answer column. The number corresponding to each day of the week is listed on the top of each sheet.

---

1. Sun 2. Mon 3. Tues 4. Wed 5. Thur 6. Fri 7. Fri

A. If today were Saturday, what would tomorrow be?. .( )

B. If today were the first day of the week, what was yesterday? . . . . . ( )

C. If yesterday were Saturday, what day is tomorrow? ( )

D. If yesterday were Sunday, what was the day before yesterday? . . . . . ( )

. . . .

There are 25 questions that get progressively harder. For example, number 24 reads:

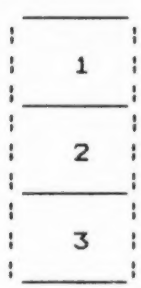
24. If the days were reversed, and if today were Saturday, and if the day before yesterday were the sixth day of the week, then what would be the day before the first day of the week? . . . . . ( )

(Extract from)

LOWRY-LUCIER REASONING

Test B

DIRECTIONS: The answer is always a number, or two or three numbers. Examples A, B, and C will be worked with you. Ask any questions about the problems at that time. No questions will be answered while the test is being taken.



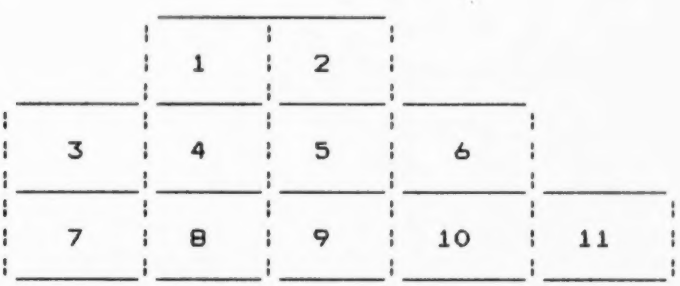
A. Imagine the little squares at the left made with matches. How many matches must be removed so that the square numbered "1" will be gone, but the other two will remain complete? (....)

B. How many matches must be removed so that square "2" will be gone leaving the other two complete? (....)

C. By removing two matches, only, which square will be entirely gone, leaving two complete squares and nothing else? (....)

. . . .

Again, the 25 questions get progressively harder. Number 25 is shown below:



25. What is the smallest sum of three squares that can be eliminated by removing three matches? (....)

Questionnaire

Thank you for participating in the experimental project. Your efforts and time are sincerely appreciated. Please answer the following questions by inserting a number from 1 to 5 that expresses your honest opinion based on the following scale: Do not put your name on the paper!

5	4	3	2	1
Strongly Agree	Agree	Don't Know	Disagree	Strongly Disagree

1. I am comfortable when using a computer. ___
2. Mathematics is one of my stronger subjects. ___
3. The instructions for solving the problems were clear. ___
4. The program had more than one objective. ___
5. I improved at solving the problems as I progressed. ___
6. The problems were too hard. ___
7. The problems were too easy. ___
8. The "windows" or "hints" were distracting. ___
9. The "hints" were helpful. ___
10. I read the "hints." ___
11. I was challenged by the problems. ___
12. I had fun doing the problems. ___
13. I understood the objective of the program. ___
14. The "hints" were always the same. ___
15. I felt I was being tested. ___
16. The mechanics of entering the answers were simple. ___
17. I could easily see the results of my choices. ___
18. The mathematics content was too easy. ___
19. I enjoyed doing the problems. ___
20. I learned from the exercise. ___

Please put a number in front of the "4C words" to show their order of execution in problem solving.

Pick only four.

____ Connecting
____ Cataloging
____ Choosing
____ Carrying
____ Classifying
____ Clarifying
____ Correcting
____ Checking
____ Capitulating

APPENDIX B

SUBJECT CONSENT AND RELEASE FORM

TO: The Registrar

I grant Mr. Juchau permission to use my age, GPA, and SAT (or equivalent score) data for the purpose of an educational research project. I understand that the data will be kept confidential and once the group statistics have been created will be destroyed. My name or other personal data will not be used in the research findings on an individual basis.

Signed _____

APPENDIX C

DETAILS FOR OBTAINING C.A.P.S. PROGRAM SOURCE CODE LISTINGS

Source code is not included in this report, but it can be obtained from the author for a nominal handling fee. Address inquiries to:

William C. Juchau
2303 Cambridge Avenue
Lakeland, FL, 33803

Please include a self-addressed, stamped envelope.